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May 18, 1988

RECEIVED
MAY 20 1988
DIV. OIL, GAS, MINING

Mr. Lowell Braxton, Administrator
Mineral Resource Development and
Reclamation Program
Division of Oil, Gas and Mining
Department of Natural Resources
State of Utah
355 West North Temple
3 Triad Center - Suite 350
Salt Lake City, UT 84180-1203

Re: Mine and Reclamation Plan,
Cane Creek Potash Mine,
M/019/005, Grand County, Utah

Dear Lowell:

On behalf of Moab Salt, Inc., owner and operator of the Cane Creek Mine, I'm enclosing, in duplicate, responses to the items on Attachment A and questions on Attachment B to your letter dated January 28, 1988. As instructed, these items are being sent to Don Ostler of the Bureau of Water Pollution Control by copy of this letter.

Very truly yours,

O. W. Gushee, Jr.

OWG:ka
0598.05
Enclosure

cc: James Huizingh (2 copies - extra copy for Carey Salt)
Eugene G. McGuire (2 copies - extra copy for Dave Edmiston)
Don A. Ostler w/encl.
Bill Strait w/encl.
Earthfax Engineering, Inc. w/encl.

5/18/88

RESPONSE TO MINE AND RECLAMATION PLAN
DOGM COMMENTS DATED 1/28/88 - ATTACHMENT "A"

(Note: See Proposed Cane Creek MRP Response Schedule Attached)

√ DOGM COMMENT #1

It is apparent that the canyon collection system below the evaporation ponds is not entirely effective in controlling salt laden runoff and seepage into the Colorado River. We will require that a plan be submitted for improving water control in this area.

In order to control both underground and surface water, we recommend that an engineered dam be constructed down to bedrock in the canyon. We also recommend that the amount of brine seepage through this area be quantified both before and after plan implementation.

RESPONSE:

An engineering firm will be employed to conduct field investigations required for system assessment and design. The in-situ collection system will be assessed and a remedial action plan developed to contain non-storm surface and subsurface flows within the closed system. Although specific details regarding the remedial-action plan can be developed only after completion of the field investigations, the plan will include detention basins which will be maintained to intercept surface discharges of brine and procedures to intercept subsurface flow with pump-back systems installed at critical locations. The field investigations will include:

~~Time frame?~~
ok

1. A hydrologic study to determine appropriate sizing of collection trenches and pumps, drains and emergency spillways.

2. A surface geophysical (seismic) study to determine depth to bedrock in those portions of the canyons where subsurface-flow collection systems are anticipated.

3. A soils investigation to provide data concerning the engineering and chemical characteristics of soils for use in designing cut-off trenches.

4. An assessment of the engineering characteristics of the soils used in dam construction to determine the necessity of re-design of the embankments.

5. A field study to delineate seepage zones originating from evaporation pond areas.

6. Preparation and implementation of a regular facilities inspection program.

7. Final design of a remedial action program.

DOGM COMMENT #2 BWPC Comment - ?

Interceptor wells have been installed along one of the faults which lies under the salt storage area. We will require that a similar well(s) be placed along the fault which underlies the brine lake unless it can be conclusively demonstrated that no seepage is possible along this fault. Additional wells may also be needed in the future if a seepage problem is indicated.

RESPONSE:

Faults and fracture systems in the vicinity of the salt storage and brine lake areas will be delineated by conducting a surficial geological field investigation and a very-low-frequency electromagnetic (VLF-EM) survey. Based on these investigations, an assessment will be made of the potential for the fractures to permit off-site migration of brine water. This assessment may include (as appropriate):

Installation of a monitoring well(s) to intercept the probable discharge fracture(s).

Performance of a pumping test(s) to determine the hydraulic characteristics of the fracture(s) and the adjacent unfractured bedrock.

Analytical or numerical modeling of the potential for off-site migration of brine in the fracture(s).

If the investigations indicate a significant potential for off-site migration of brine through the fracture(s), a recovery plan will be developed and implemented to minimize this potential. This plan may include:

Conversion of the monitoring well(s) to recovery well(s).

Piping of existing brine water return stream(s).

Design of a pumping plan to capture brine contamination and minimize the potential for off-site migration.

DOGM COMMENT # 3 BWPC

The plan does not contain brine water balances. We will require that a water balance be submitted for each major component of the site so that any brine leakage can be located, quantified, and eventually mitigated.

The information necessary to prepare water balances may be readily available to you from records that you have kept on site. If not, we recommend that a monitoring system be set up that will allow quick and accurate collection of the necessary data. We also recommend that water samples be taken from the river, both immediately above and below the site. These samples will help identify current levels of salt contributions to the river and provide a benchmark to judge the effectiveness of future mitigation practices.

RESPONSE:

The current piping distribution system, injection and recovery well network, evaporation pond operations, and pump-back system will be assessed to delineate obvious points of leakage. Where feasible, the system will be simplified and repaired.

A program will be designed and implemented to produce brine water balances relating to each major component of the site. The overall summary reports will be submitted annually. The brine water balances will be of limited use to judge the effectiveness of future mitigation practices because of the inherent inaccuracies of such balances. For example, the surface area of the ponds is approximately 407 acres. Therefore, an error of one inch in the annual evaporation rate would cause an 11,000,000 gallon error in the water balance and a 17,000 ton error in the amount of salt that left the ponds. The water balance procedure will be prepared and will include a mathematical analysis of the accuracy of the various factors to assist in determining the feasibility of using the balances in monitoring losses. However, we believe the year to year use of material balances with appropriate experience factors to correct data will be useful over the long range of operations to monitor performance.

Collection of representative samples from the Colorado River will be very difficult immediately up- and downstream from the site. As indicated by the National Handbook of Recommended Methods for Water-Data Acquisition published by the U.S. Geological Survey (1977, as amended), "larger streams require sampling of several verticals at equal width increments or at centroids of equal discharge. . . . Generally, 10 to 20 verticals will give an accurate discharge-weighted concentration by the (equal-width-increment) method." As a result, most such samples are collected only where bridges are present or where a cable can be feasibly stretched across the river for suspension of a sampling carriage. Neither of these conditions exist immediately up- or downstream from the site. why not use boat or raft?

Nonetheless, Moab Salt will identify two locations upstream and two locations downstream to be used as sampling points. In lieu of the collection of representative depth-integrated samples from the river, Moab Salt proposes to collect grab samples from these stations on a quarterly basis from the edge of the river beginning in the second quarter of 1988. These four samples will be collected within 10 feet of the west bank of the river immediately below the surface of the water. The four samples will be analyzed for:

Calcium	Bicarbonate
Magnesium	Carbonate
Potassium	Chloride
Sodium	Sulfate
Specific conductance	Total dissolved solids

Results of these analyses will be included in the annual reports. In interpreting the results of these analyses, the relative representativeness of the samples must be given due consideration.

DOGM COMMENT #4 BWPC

* The design plans for the catch ponds below the brine lake dam must be submitted. We would also like to see copies of the reports for the grouting of the open joints in the foundation of the reservoir and in the dam abutments.

The above referenced plans should be evaluated in conjunction with the brine water balance. If a seepage problem is indicated, it may be necessary to modify the catch pond or to construct intercept wells down gradient from the catch pond.

RESPONSE:

No construction engineering plans or drawings were developed prior to building the catch ponds below the brine lake. It is a field-assembled system constructed after installation of the brine-lake dam. Water present in the upper catch pond is from leakage emanating from the joints which intersect the brine lake. This seepage does not appear to affect the integrity of the structure. In the 26 years since installation (1962), no deterioration of the dam has been noted.

To evaluate the potential for uncontrolled seepage of brine beyond the catch pond, a VLF-EM survey will be performed southeast of the catch pond and backhoe test pits will be excavated to bedrock downstream from the pond within the arroyo. If seepage is found to be following the surface of the bedrock or if significant fractures are observed, then an appropriate remedial action plan will be developed and implemented.

Records were kept of a grouting program instituted for the brine-lake dam following its construction. When fluid was placed behind the dam, a small leak appeared at the toe of the dam, thus requiring construction of the catch pond and grouting to control leakage. A memorandum to file from James H. Ogg, dated July 19, 1962, is attached which summarizes the grouting work.

Solid waste Mgmt → #5 Storm water Ground water Recharge
+ BWPC ???
*

DOGM COMMENT # 5

The leaching of the proposed landfill was strongly objected to by the Department of Environmental Health. We will require that an alternate plan be proposed or a commitment to the following:"

a. Lining the landfill; and,

b. limiting the amount of salt placed into the landfill as much as is practical; and,

c. constructing and operating the landfill in accordance with the applicable state and federal regulations in force at the time of reclamation.

RESPONSE:

Moab Salt will revise the reclamation plan to ensure that the waste-storage area (formerly termed the "landfill") is planned and constructed in accordance with applicable state and federal regulations in force at the time of plan development. Care will also be taken to limit the quantity of salt-contaminated materials that are placed in the waste-storage area.

At the end of normal plant operations, the largest quantity of salt-contaminated materials will probably be associated with the evaporation ponds. This will consist primarily of the compacted salt base that cannot be easily scraped without damaging the plastic liner. It is currently anticipated that this compacted salt base, the plastic liner, and the upper inch of soil will be removed from most of the ponds and deposited in selected remaining lined evaporation ponds where the salt-contaminated materials will be leached. Leaching will continue until the leach water is salt-saturated. This leach water will then be discharged to another lined pond for evaporation or pumped directly into the mine cavity. If the leach water is discharged to an evaporation pond, the resulting salt will be processed in the normal manner or pumped into the mine cavity. Fresh leach water will then be added and the cycle continued until additional leaching becomes ineffective.

It is recognized that not all salt will be removed from the evaporation ponds using the fresh-water dissolution. However, this process will greatly reduce the quantity of salt-laden material that is eventually disposed of in the waste-storage area.

which ponds?

Current regulations do not require the construction of a liner beneath non-hazardous waste-storage areas. Nonetheless, Moab Salt will plan to utilize one or more of the abandoned evaporation ponds as the location of the waste-storage area. Under this scenario, the compacted salt base would be maintained in the chosen pond(s) to protect the liner and support equipment that is used to emplace the waste materials.

will need revised plan before proceeding

Revisions to the design of the waste-storage area will be made in a manner that ensure that the area is planned and constructed in accordance with applicable state and federal regulations in force at the time of plan development.

DOGM COMMENT #6

The design assumptions used for handling of storm water runoff during reclamation are minimum estimates at best. We will require that these systems be redesigned when the canyon collection system is improved and more accurate data is available.

look up

Note: On page 11-8 you state that runoff from drainages in unaffected areas nearby will be obtained as a standard of comparison to samples from the reclaimed areas. We think that this is a good approach, but wish to make it clear that a discharge permit will probably also be required by other state or federal agencies at the time of reclamation.

RESPONSE:

The adequacy of the runoff-control facilities will be assessed following improvement of the canyon-collection system and the collection of more accurate hydrologic data. If the runoff-control facilities are then determined to be undersized, design revisions will be made and implemented.

Until reclamation is complete, all pump-back systems will be maintained to minimize the potential for brine waters to migrate into the Colorado River. If required, a discharge permit will be obtained from the governing regulatory agencies.

DOGM COMMENT #7

Speak w/ham concerning

We will require that Moab Salt demonstrate that subsidence will not be a problem over the 100 year mine life or commit to subsidence monitoring.

We recommend the second alternative and that permanent, well protected survey stations be installed. A summary of the monitoring results would have to be included with the annual report during those years that a survey is conducted.

RESPONSE:

A subsidence monitoring plan will be developed and submitted. This plan will include selection of points for permanent installation of survey markers on both the flank and crest of the anticline as well as over the primary mine area and points contiguous to it. Data from these survey points will be submitted to DOGM with the annual reports.

DOGM COMMENT #8

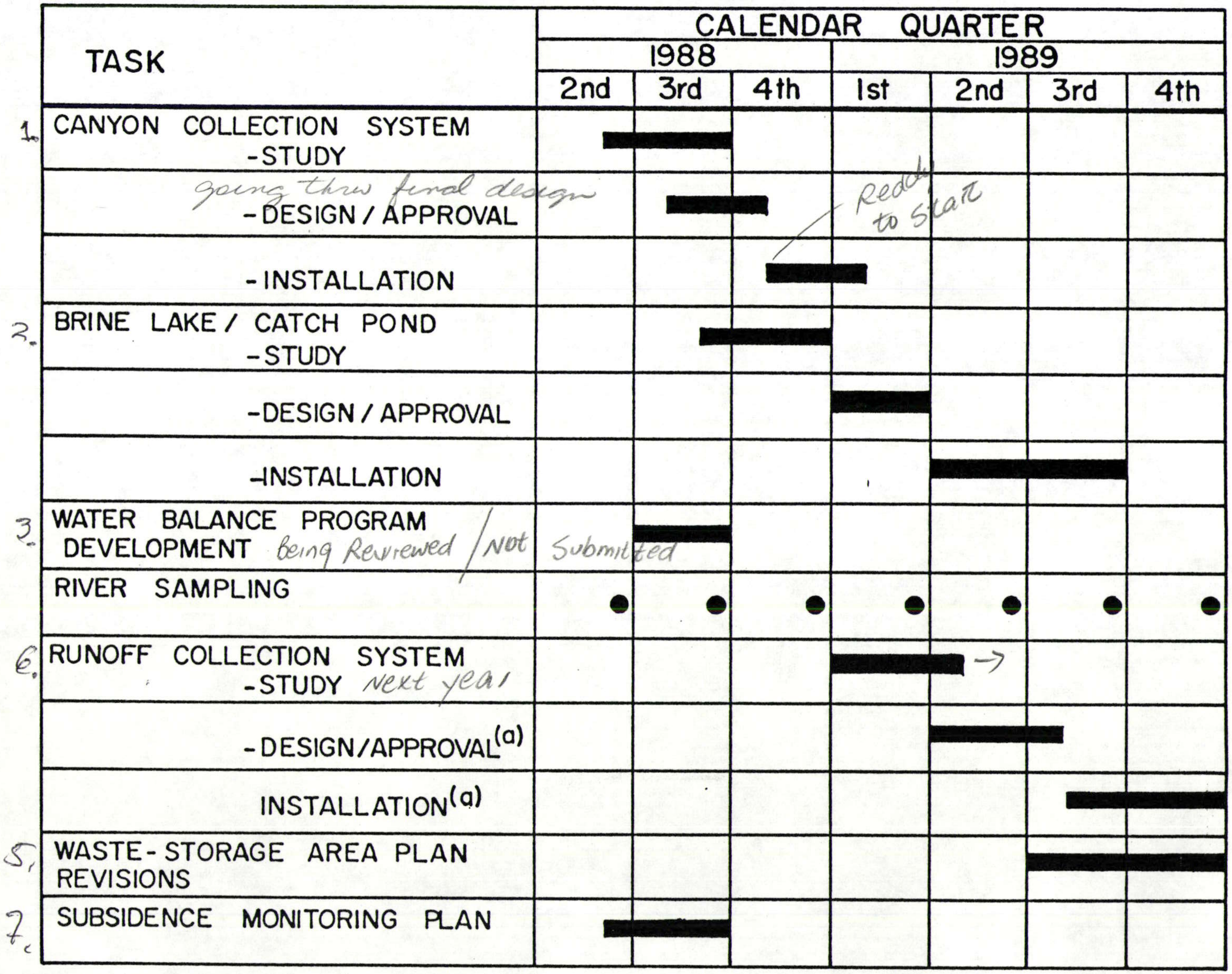
We will require that a short summary of any water monitoring, brine spills, and liner repairs be submitted each year in the annual report to the Division. The Bureau of Water Pollution Control has also indicated that they would like to have some type of annual/quarterly reporting.

We also recommend, if not already in place, that a detailed record of water monitoring, spills, liner repairs, etc. be kept at the mine site and be available for inspection by regulating agencies.

RESPONSE:

Water monitoring data, spill records, and pond liner maintenance reports will be submitted with the annual reports. These data will be kept on file during the year for inspection by regulatory agencies.

PROPOSED CANE CREEK MINE
MRP RESPONSE SCHEDULE



(a) AS REQUIRED

MAY 9, 1988

EarthFax

5/18/88

RESPONSE TO MINE AND RECLAMATION PLAN
DOGM COMMENTS DATED 1/28/88 - ATTACHMENT "B"

DOGM COMMENT

1. Part 12-2 of the plan states that the salt contaminated soil at the plant site will be leached until the SAR and EC of the first three feet of soil are below 14 and 8 MHOs, respectively.

   a. Why were these MHO levels chosen?

   b. Will the same soil testing and success criteria apply to the evaporation ponds and raw salt storage area?

RESPONSE:

   a. Based on the literature and our experience in arid lands reclamation lowering the SAR value to 14 and the EC to 8 MHOs will allow for reestablishment of adequate vegetative cover on the Cane Creek site. These SAR and EC values meet the DOGM standards for suitable topsoil. (See the following Table 1.)

   b. Yes.

in poor range

- SAR should be < 14
- match SAR surrounding soils

TABLE 1

DIVISION OF OIL, GAS AND MINING
GUIDELINES FOR MANAGEMENT OF TOPSOIL AND OVERBURDEN
(Revised April, 1988)

see if lit verifies

Table 2. Overburden Evaluation for Vegetative Root Zone*

	Good	Fair	Poor	Unsuitable
Electrical Conductivity	0-2	2-8	8-15 8	Greater than 15
Sodium Adsorption Ratio (SAR)	< 4	5-10	10-12 Fine Texture. 10-15 Coarse Texture. 14	>12 Fine Texture. 15 >Coarse Texture.

* Many native species have their roots in soils that are determined poor to unsuitable by these values. Occasionally soil materials rated good by these standards have poor vegetation success. Therefore, plant growth trials may be needed where re-establishment of native plants is desirable.

How accomplished—?

Big question here is capillary rise of the underlying salts via action of plants and water in soil.

DOGM COMMENT

2. The reclamation plan calls for the leaching of the first three feet of salt contaminated soils in the various mine areas. This is adequate for revegetation purposes. We are concerned, however, that salt concentrations below the three foot level will eventually leach into the Colorado River.

   a. How much salt will be left below the three foot level after leaching?

   b. To what degree will this remaining salt be susceptible to natural leaching after reclamation?

RESPONSE:

Section 11.C.2. of the permit application document contains results of soil tests used to estimate the quantity of salt contained in the first three feet below the pond liners. The test information can also be used to estimate salt content in the sand below three feet. The second test sample was taken approximately 7 feet below the pond liner. It appears from the test results that the salt concentration is evenly distributed with depth and is essentially sand saturated with brine. The pond bases contain variable thicknesses of compacted sand 1 to 20 feet thick above sandstone bedrock. The average thickness of sand under the entire pond area is estimated at 8 feet. If all the sand below the ponds is assumed saturated with brine, then the volume of brine-saturated sand is calculated to be:

407 acres x 43,560 sq. ft./acre x 8 ft. = 141,800,000 cu. ft.

Using the soil test results as a basis, a 2.6% average salt content will be assumed. Therefore the sand beneath the ponds contains:

$$\frac{141{,}800{,}000 \text{ cu. ft.} \times 120 \text{ lbs/cu. ft.} \times .026}{2000 \text{ lbs/ton}} = 221{,}000 \text{ Tons of Salt or } 543 \text{ tons/acre}$$

Where density of compacted sand = 120 lbs/cu. ft.

There is no known simple and straightforward method of determining the amount of salt in the sandstone joints and bedding planes beneath the evaporation ponds. The calculation is, of course, somewhat hypothetical but does illustrate the intent that the plan be sufficient to accomplish a reasonable reclamation standard.

The current reclamation plan calls for removing 250 tons/acre or approximately 46% of the total amount calculated. A leaching program aimed at removing all or nearly all of the salt present would multiply the volumes of leach brine generated. The current plan estimates a total of 109 million gallons of leach brine at 75% saturation in dissolved salts. An expanded leach program would result in the leach brine becoming much more dilute in order to achieve final dissolved solids concentrations that are close to background values. If the average leach brine percent saturation decreased, to say 25%, then the total volume would increase to:

109 MM gal. x (75/'5 + 650/250) = 610 MM gal.

Based on field observations, the salt in the subsoil would be essentially immobile; therefore, leaching "all" of the salt out is not necessary and would drastically increase the cost and the duration of the final reclamation project.

In Appendix 3, "Salt Seeps in Proposed Evaporation Pond Areas", dated April 3, 1970, several important observations were made before construction of the evaporation ponds.

1. The ground water seeps in the area were few in number; a total of six over an area greater than 1,000 acres.

2. The flows from the seeps were very small. Only two of the seeps (No. 1 and No. 3) had sufficient flow to obtain water samples. The narrative in Appendix 3 contains no estimates of flow rates; however, the observation was made that none of the flows progressed any great distance before evaporating and leaving salt incrustations behind.

3. The water in the seeps was of poor quality. This is evident from the formation of a crust high in salt and sulfate. (See solid and water analyses in Appendix 3 of permit application document.)

It should be noted that seeps in the area are typically more active in the spring. The investigation in Appendix 3 was made in the spring. An inspection of the original photographs indicates a lack of vegetation around most of the seeps. This is strong evidence that the seeps regularly dried up. It should also be noted that adjacent drainages in the areas nearby remain dry throughout the year, except for during and immediately after storms.

In conclusion, it may be stated:

1. Minor salt buildups around ground water seeps was a natural occurrence in the evaporation pond area before construction of the ponds.

2. After reclamation of the pond area, ground water movement is expected to return to its natural rate that existed prior to pond construction.

Incomplete leaching of the salt below the ponds may result in a somewhat greater buildup of salt crust from the natural seeps. But after reclamation, there will be no ponds supplying a constant head for these seeps and virtually all precipitation will either be removed from the soil through evapotranspiration by plants, evaporate, or runoff. As a result, the surface seeps will return to their premining flow rates and reclamation runoff samples obtained from reclaimed areas should not vary noticeably from the runoff that occurs in unaffected areas in this region. The leaching plan as presently proposed should meet all regulatory requirements.

DOGM COMMENT

3. What measures are employed at the plant site to minimize salt laden runoff from the salt storage areas and contamination of the ground water?

Note: We recommend that all salt storage areas at the plant site be underlain with a synthetic liner and surrounded by lined storm drainage collectors.

RESPONSE:

The salt that was temporarily stockpiled on the ground beyond the lined pad at the feed receiving storage area has now been reclaimed. Drawing 11-4 has been reworked and resubmitted (attached) to show the additional details requested: The two salt stockpile areas are lined with PVC and hypalon. The brine and runoff from the stockpiles are collected into lined sumps and piped to the tailings treatment building.

DOGM COMMENT

4. The reclamation plan calls for the building of a leach brine collection trench downgradient of the plant site to collect the leach waters. Is a similar natural leaching of salt laden soils at the plant site occurring at this time?

Note: If this appears to be a problem, we would recommend that a minimum of three shallow monitoring/collector wells be placed in the proposed trench area at this time.

RESPONSE:

Because of the low annual rainfall, there is no significant movement of salt through the soil on the plant site. The process building and warehouses were built on the high ground between two arroyos. If there was significant salt migration through the soil from the plant, we would see salt seeps in the rock outcrops in the arroyos similar to those in the canyons below the ponds. There are no active seeps or evidence of past seeps in either of the arroyos.

DOGM COMMENT

5. The plan states that the brine lost along the faults of Wells TP-1, 2, and 3 is reclaimed by maintaining the local water table below river level. Since the brine is considerably denser than the river water, it is necessary that the brine level be kept a substantial amount below the river level. Is this being done? (Please attach calculations to show that the maintained level is adequate.)

RESPONSE:

We are currently maintaining the level in the TP-3 well approximately 34 feet below the bottom of the river. We have accurate measurements of the surface river level and the depth of the TP-3 well below the surface. The bottom of the river and the elevation at the TP-3 well site have been estimated. We plan to survey the TP-3 well site to get an accurate elevation. Estimating the level of the river bottom at 10 feet below the surface is conservative and a more accurate elevation is not needed.

Elevation of TP-3	4,090
Depth to Current Fluid Level	200
MSL Elevation of Fluid Level	3,890 ft.
MSL River Elevation	3,934
Depth of River	10
MSL of River Bottom	3,924 ft.
Difference	34 ft.

(Fluid Level in TP-3 is lower than the River Bottom)

TEXAS GULF SULPHUR COMPANY - MOAB, UTAH

INTER-OFFICE COMMUNICATION

MEMORANDUM

DATE: July 19, 1962

TO: Files

FROM: James H. Cigg

SUBJECT: Test Hole Drilling and Grouting Program - Tailings Dam Area - North End

INTRODUCTION

The program was started on June 13, to evaluate and possibly seal off a small leak which appeared at the toe of the tailings dam, near the north end. This program included drilling twelve shallow test holes to determine the course of the water and three grout holes drilled from the top of the dam near the north end to try to seal off the leak.

BACKGROUND

In May of 1961, Woodward, Clyde, Sherard and Associates presented the Company with a report covering a geologic examination of the tailings dam area. In this report, they stated that water could possibly travel along the following courses:

1. Along the primary joints
2. Along the secondary joints
3. Through inter-granular voids
4. Along bedding planes

The report went on to say that they did not believe that the primary and secondary joints were "open sufficiently to permit" significant amounts of water to travel along them. They also mentioned that if water did pass along these joint planes, it could be grouted off. They stated that any amount of water through inter-granular voids would be very small and slow, and that if water did follow this course, it possibly would eventually seal itself off as salt deposited out from the solutions behind the dam. They mentioned that in their opinion, the most likely line of ground water movement from the reservoir would be along the bedding planes. The report recommended an impervious core for the dam to prevent possible leakage.

On February 9, 1962, a memorandum was sent to J. Frank Henderson concerning an investigation of a "mud seam" in the tailings dam area. This memorandum does not concern our particular problem at the present, because the seam is at present above the water now contained behind the dam. However, it was stated in this memorandum that the ability of these seams to carry water could not be determined and that the particular seam investigated passed at least 26 feet below the keyway of the dam. This is mentioned because it appears that a similar type seam is causing the initial problem in this case.

As the dam was being completed, and after it reached a specified height, a comparatively small amount of water was allowed to accumulate behind it. On June 11, a small (2 gpm estimated) leak appeared at the toe of the dam on the east side, near the north end, and the present investigation was initiated.

THE TEST PROGRAM

Chemical dye was introduced into the water at a spot above the dam where it appeared to be entering the thin silty seam. In a matter of thirty minutes, all the dye disappeared into the ground, however, none of this dye appeared on the other side of the dam, a distance of approximately 370 feet.

A series of shallow test holes was drilled as close to the abutment as possible, near the north end of the dam, both down in the lake bottom and along the top of the escarpment to the north. Please refer to the attached map.

The table below is a tabulation of the information obtained from drilling the test holes. The strike and the dip of the bed which appeared to be the initial carrier bed was determined along with the attitudes of the various joints in the area.

Table 1

Test Hole Information

Test Hole No.	KB Elevation	Total Depth	Condition of Hole
1	4.0 ft	30.0 ft	Dry
2	3.5 ft	34.5 ft	Dry
3	4.5 ft	25.0 ft	Wet
4	4.0 ft	26.0 ft	Wet
5	4.5 ft	38.0 ft	Wet
6	4.5 ft	94.5 ft	Dry
7	4.5 ft	90.0 ft	Dry
8	4.5 ft	110.0 ft	Dry
9	4.0 ft	110.5 ft	Dry
10	3.5 ft	125.0 ft	Wet
11	4.5 ft	35.0 ft	Wet
12	4.0 ft	35.0 ft	Wet

This table indicates the condition of the holes when they were initially drilled. On June 19, the holes had been located horizontally and vertically, and were then measured in detail, resulting in the following table:

Table 2

Test Hole Information

Test Hole No.	Total Depth	Top of Water (from Surface)	Top of Water Sea Level Datum
1	30.70 ft	Dry	Dry
2	33.65 ft	32.55 ft	3990.75 ft
3	24.75 ft	14.50 ft	4004.60 ft
4	25.15 ft	14.00 ft	4004.50 ft
5	32.35 ft	23.60 ft	4004.90 ft
6	94.65 ft	94.55 ft	3987.95 ft
7	97.15 ft	96.55 ft	3983.85 ft
8	109.20 ft	108.30 ft	3969.60 ft
9	106.85 ft	Dry	Dry
10	125.20 ft	66.35 ft	4006.35 ft
11	34.10 ft	20.35 ft	4011.55 ft
12	26.65 ft	20.45 ft	4008.45 ft

The water level behind the dam at the time of this measurement was at 4007 feet.

Twenty-five days later, on July 13, the following measurements were made. At this time, the water level behind the dam was at 4009 feet.

Table 3

Test Hole Information

Test Hole No.	Total Depth	Top of Water (from Surface)	Top of Water Sea Level Datum
1	30.70 ft	26.50 ft	3990.60 ft
2	33.65 ft	15.15 ft	4008.15 ft
3	24.75 ft	11.25 ft	4007.85 ft
4	25.15 ft	8.50 ft	4010.00 ft
5	32.35 ft	19.50 ft	4009.00 ft
6	94.65 ft	93.15 ft	3988.35 ft
7	97.15 ft	94.65 ft	3985.75 ft
8	109.20 ft	90.20 ft	3987.70 ft
9	106.85 ft	Dry	Dry
10	125.20 ft	Grouted	Grouted
11	34.10 ft	14.50 ft	4017.40 ft
12	26.65 ft	12.15 ft	4015.30 ft

Comparison of the sealevel depths of the water in this table with the preceding table shows that the water levels increased in all but one instance, and that was test hole number 6.

The table below compares the depths at which water would have been encountered if it were contained completely in the "mud seam", by which it appears to be entering the rock with the depth of water measured on June 19, when the water level was 4007 feet and the depth of water as measured on July 13, when the water level was 4009 feet. All figures in this table are rounded off to the nearest foot.

Table 4

Test Hole Information

Test Hole No.	Theoretical Sea Level	Measured Sea Level 6-19	Measured Sea Level 7-13
1	4002 ft	Dry	3991 ft
2	3997 ft	3991 ft	4008 ft
3	3992 ft	4005 ft	4008 ft
4	3998 ft	4005 ft	4010 ft
5	3992 ft	4005 ft	4009 ft
6	3982 ft	3988 ft	3988 ft
7	3982 ft	3984 ft	3986 ft
8	3981 ft	3970 ft	3988 ft
9	3987 ft	Dry	Dry
10	3981 ft	4006 ft	Grouted
11	3997 ft	4012 ft	4017 ft
12	4006 ft	4008 ft	4015 ft

From the information shown on the tables above, it is indicated that the water is travelling along a combination of courses. It appears to enter the "mud seam" mentioned, but then it seems to follow the extensive joint pattern in an eratic nature. It is quite possible that the flow causing the leak follows the seam down some distance and then at a point close to the abutment, it goes underneath the keyway itself, or follows the interface between the dam core and the abutment. In order to test the flow, over 200 barrels of heavily dyed water were pumped into test hole number 10. No pressure developed, and the dye did not appear on the east side of the dam, a distance of approximately 175 feet.

On the basis of the test hole program, it was decided to drill some holes into the bedrock immediately north of the core, grout these holes, and then review the situation.

GROUTING PROGRAM

Three test grout holes were planned, spaced fifty feet apart, along the center line of the dam keyway, starting 100 feet south of the 0.00 point established by Stearns on the center line, These wells were drilled at an angle to the north anywhere from 10° to 14° in an attempt to cut as many of the near vertical joints and fractures as possible. Location of these holes is shown on the map and the accompanying cross-section. The holes were grouted in stages of 25 feet, generally, starting with a very thin slurry, which was thickened if no pressures were encountered. A limit of eighty pounds pressure was used as the stopping point. Below is listed the well data and the amounts of cement injected into the hole. This resume' will be outlined in chronological order.

June 26, 1962: Test Hole #13; angle 13°; bedrock encountered at 68.5 feet; casing set at 68.5 feet; cemented from top to bottom.

June 27, 1962: Test Hole #13; drilled out from the bottom of the casing to a depth of 95 feet. The hole was dry.

Pumped	Barrels Slurry	Mix	Sacks Cement	Pressure
1	4.5 bbls	1:1	4.5	Up to 40#
2	9.0 bbls	1.5:1	13.5	40#

June 28, 1962: Test Hole #13; redrilled wet cement to 95 feet.

1	5.0 bbls	1.5:1	7.5	40#
2	4.0 bbls	2:1	8.0	Up to 80#

June 29, 1962: Test Hole #13; redrilled wet cement to 95 feet.

1	10.0 bbls	2:1	20.0	40#

July 2, 1962: Test Hole #13; redrilled wet cement to 95 feet.

1	4.0 bbls	0:1	0	0
2	15.0 bbls	2:1	30	40#
3	1.0 bbls	3:1	3	Sealed rapidly to 80#

July 3, 1962: Test Hole #14; angle 14°; bedrock at 11 feet; set 22 feet of casing, cemented top to bottom.

July 5, 1962: Test Hole #14; drilled out from bottom of casing to a depth of 47 feet. The hole was dry.

1	3.0 bbls	0:1	0	0
2	10.0 bbls	0.5:1	5	0

	Pumped	Barrels Slurry	Mix	Sacks Cement	Pressure
	3	20.0 bbls	1:1	20	20#
July 6, 1962:	Test Hole #14; redrilled wet cement to 47 feet.				
	1	5.0 bbls	1:1	5	0
	2	20.0 bbls	1.5:1	30	20#
	3	8.0 bbls	2:1	16	40 to 80#
	4	3.5 bbls	1.5:1	5.25	70# and sealed
July 9, 1962:	Test Hole #14; redrilled wet cement to 47'; drilled to 72'. The hole was dry.				
	1	1.1 bbls	0.5:1	0.5	80#
	2	1.0 bbls	1:1	1	Sealed at 80#
July 10, 1962:	Test Hole #14; redrilled wet cement to 72'; drilled to 97'. The hole was dry.				
	1	1.5 bbls	1:1	1.5	70#
	Test Hole #14; drilled to 122 feet. The hole was dry.				
	1	1.5 bbls	1:1	1.5	80#, sealed
	Test Hole #10; hole already drilled to 125 feet, set with 20 feet of 2" casing; measured 63 feet of water standing in the hole; no evidence of grout.				
	1	26.0 bbls	1:1	26	0
July 11, 1962:	Test hole #10				
	1	4.0 bbls	1:1	4	0
	2	22.0 bbls	2:1	44	40#
	Test Hole #15; angle 10°; found bedrock below 3 feet of fill; set casing at 10 feet, cement from top to bottom.				
July 12, 1962:	Test Hole #10				
	1	28.0 bbls	2:1	56	60#
	Test Hole #15; drilled out from bottom of casing to a depth of 35 feet.				

Pumped	Barrels Slurry	Mix	Sacks Cement	Pressure
1	11.0 bbls	0.5:1	5.5	50#

July 13, 1962: Test Hole #15; redrilled wet cement to 35 feet; drilled to 60 feet. The hole was dry.

1	1.0 bbls	0.5:1	.5	80#

Test Hole #15; drilled to 85 feet. The hole was dry.

1	3.5 bbls	0.5:1	1.75	80#

July 16, 1962: Test Hole #15; redrilled wet cement to 85 feet. Drilled to 105 feet, hit water. Drilled to 115 feet.

1	4.0 bbls	0.5:1	2	20#
2	10.0 bbls	1.1	10	40#
3	1.5 bbls	2.1	3	80# sealed

The following table is a summary of the grouting program, showing the footages drilled and redrilled, the barrels of slurry put into each hole, and the sacks of cement in each hole.

Table 5

Grouting Summary

Test Hole No.	Footage drilled and redrilled	Barrels of Slurry	Sacks of Cement
10	125.0	80.0	130.0
13	448.5	52.5	86.5
14	285.0	74.5	85.75
15	305.0	30.0	22.75
Totals	1163.5	237.0	325.00

At no time did the grout appear at the surface in the area or at the leak in the toe of the dam. Also, as mentioned above, no grout appeared in any of the other test wells.

FUTURE PROGRAM

The following is recommended as an extension of the present existing program.

1. Drill test hole #16, located half way between test holes #13 and #14, at an angle of 10° to 15°. This well should be drilled to the bedrock at plus or minus 40 feet drilling depth, with a 5-1/8" bit. Drill one foot into the Bedrock and clean the hole thoroughly. Not any moisture contacted. Then core the hole continuously to a depth of 120 feet. The core bit will be furnished by Texas Gulf. All the core should be marked and properly preserved. Again note any water that may be encountered. After the coring is through, set 4" inside diameter casing as before in the hole into bedrock, cement properly and then grout the hole, starting with a half sack per barrel slurry for ten barrels, increasing to 1:1 for ten barrels, and finally going up to 2:1 or 3:1 if necessary.

2. Drill hole #17 midway between test holes #16 and #13. This hole should be drilled straight down to the bedrock at plus or minus a drilling depth of 85 feet with a 5-1/8" hole. The hole should be planned to the east of the center line of the dam in order to miss the casing in test hole #13. The hole should penetrate bedrock one foot, be cleaned thoroughly, and 4" inside diameter casing set and cemented as before. The hole should then be deepened 25' and grouted as test hole #16. All water occurances should be noted.

3. It is suggested that the present drilling contractor and his crews continue with the program. Detailed plans will be provided them and it is felt they can competently complete the job for us at a minimum cost.

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JHO/pam
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